The results obtained from the experiment are summarized below.

I. The control (No. 1).

After 3 days: The methylene blue strip was reduced throughout the lower 4 cm.

After 6 days: The methylene blue strip was reduced throughout the entire length except for the top 1·5 cm. The Nile blue strip was partially reduced in all but the top 1·5 cm. The neutral red strip was irregularly reduced at 3 cm., 5·5 cm., 10·5 cm. and 13 cm.

After 7 days: There was no appreciable change.

After 14 days: The soil was slightly dry and the subsequent entry of oxygen re-oxidized the dyes as far down as 4 cm. Some fungal growth was visible on the filter paper. There was a macroscopic growth of algae on the surface of the soil.

II. Soil and Derx's mineral solutions (Nos. 2, 4, 6).

After 3 days:

In the light: no reduction was evident.

Surface light: no reduction was evident.

In the dark: no reduction was evident.

After 6 days:

In the light: a thin green algal layer had appeared on the soil surface. Methylene blue was reduced from 2·5 cm. to 10 cm., Nile blue was reduced from 2·5 cm. to 10 cm. and neutral red was reduced from 5·5 cm. to 8·5 cm.

Surface light: a thin green algal layer had appeared on the soil surface and the reduction of the dyes was similar to that in the light.

In the dark: the soil was very moist; there was no macroscopic growth of algae on the surface and the reduction of the dyes was similar to the previous two cases.

After 7 days:

In the light: there was no change in the dyes; a heavy growth of algae was present on the surface of the soil and also in the air spaces throughout the soil in parts which were within the reduction zone and exposed to the light at the edge of the beaker.

Surface light: there was no further reduction in the dyes, the surface algal growth was greater.

In the dark: there was no further reduction in the dyes and no algal growth.

After 14 days:

In the light: the surface algal growth had increased and the large areas of algal growth which were made possible by the presence of air bubbles in contact with the light had regenerated sufficient oxygen by photosynthesis to re-oxidize completely the dyes in the immediate vicinity of the algal zone.

Surface light: a thick green mat of algae had further developed on the surface but, due to the absence of light below the surface, there was no re-oxidation in this case.

In the dark: no further change had occurred.

An entirely new experiment was set up in which the dye pheno-safranin, which had proved unsatisfactory in our case, was replaced by Janus green ($rH_2 = 5{\cdot}2$), and in which the large air bubbles, so prominent in the former experiment, were avoided by careful shaking of the soil on addition to the beaker. It was then found that, in the absence of air bubbles, the algae grew only on the surface, below which the dyes remained permanently reduced.

III. Soil and Derx's mineral solution and glucose (Nos. 3, 5, 7).

After 3 days:

In the light: methylene blue was reduced from 0 cm. to 2·5 cm. and again from 7·5 cm. to 10 cm.

Surface light: methylene blue was reduced from 0 cm. to 7·5 cm.

In the dark: methylene blue was reduced from 0 cm. to 7·5 cm.

All beakers were completely swamped to the brim with water due to the raising of the water level by the gas formed as a result of fermentation. There was a very strong smell typical of an anaerobic fermentation and a heavy surface scum on the water.

After 6 days:

In the light: methylene blue was reduced completely from 4 cm. to 6·5 cm. and from 10 cm. to 15 cm. while partial reduction occurred at 0 cm. to 4 cm. and 6·5 cm. to 10 cm. The Nile blue was partially reduced at 1·5 cm. to 2·0 cm. and the neutral red was reduced at 7·5 cm. to 15 cm.

Surface light: methylene blue was reduced at 2·5 cm. to 7·5 cm. and partially reduced at 7·5 cm. to 15 cm. The Nile blue was reduced at 2·5 cm. to 12·5 cm. and partially reduced at 12·5 cm. to 15 cm.

In the dark: there was complete reduction of the methylene blue and Nile blue.

In the three beakers the odour of fermentation still persisted; there was a marked irregularity and pocking in the soil due to the liberation of gas from the soil and the subsequent lowering of the water level to replace the gas. Water was added where needed.

After 7 days: As at 6 days, but the odour of fermentation had disappeared in all cases. There was no sign of any algal growth.

After 10 days: No change in the reduction of dyes but the surface of the soil showed signs of the beginning of algal growth in the presence of light only.

After 14 days: There was a definite algal growth in the presence of light only.

Soil samples were taken at this stage. The qualitative tests with Fehling's reagent did not show the presence of any reducing substances in the beakers to which glucose had originally been added. The algal populations were estimated by the direct fluorescence microscope technique for all samples. Results are summarized in the Graph II. Two beakers (Nos. 3 and 5) showed practically no growth of algae. When algae were present, most were confined to the top 5 mm. and yet algae could be found at 1·5 cm. depth, but in such low numbers that it was doubtful if this was not due to washing down with water when the samples were taken. Two days after this stage a growth of algae was noticed in beaker No. 5, which had been supplied with added glucose. A green surface layer was formed within five days. In the experiment kept completely in the dark there was no algal growth visible on the surface of the sand, even after 45 days.

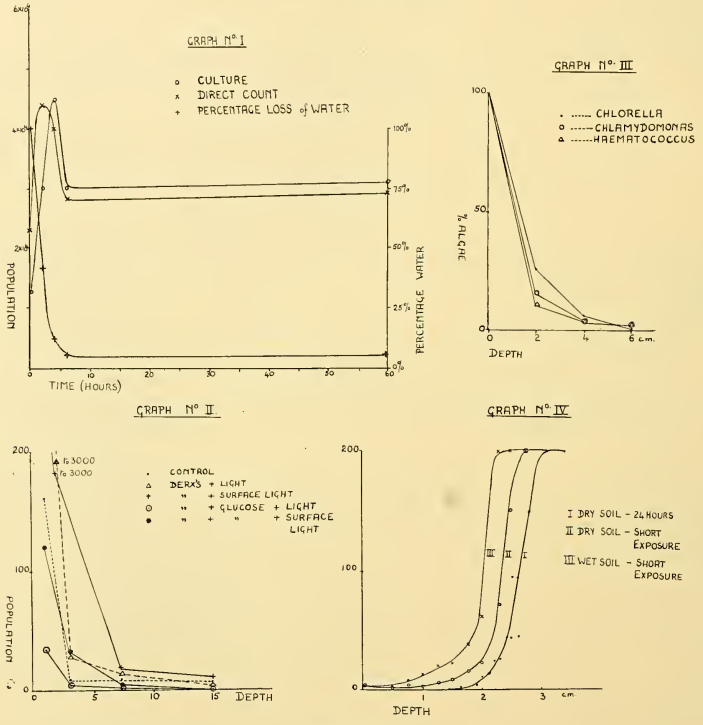
It has already been shown that the growth of algae in the dark, even in the presence of organic matter, is most unlikely. Therefore, was the presence of algae at 1·5 cm. below the surface of the soil due to the penetration of air and light to this depth or to the effect of washing down by water or a combination of both factors?

Precipitation of Algae by Water.

A river sand was washed with water until it was practically free of algal cells. A large filter funnel was plugged with glass wool and filled with the sand. A complete water column was set up in the sand by allowing water to filter through until all air bubbles were excluded, leaving a surface layer of about 1 cm. head of water, and blocking the exit by means of a clamped rubber tube. A few c.c. of a suspension of a pure culture of algae, which had been examined to ensure that all the cells were well distributed throughout the water, was added to the water layer above the sand and well mixed with it. The funnel was opened for about five minutes and the water allowed to drain

away slowly into a beaker until all the free water had filtered off. The centre of the sand was cut into a small block and the number of algal cells deposited at different levels was counted. In order to determine the distribution of different morphological types of algae through the soil three pure cultures were used, namely, *Chlorella* ($9 \times 8\mu$), *Chlamydomonas* ($20 \times 13\mu$), and *Haematococcus* (50μ diameter). The results may be seen in Graph III.

Algal cells were found throughout the top 6 cm. of the soil, but *Chlorella* cells were present in the water which had filtered through the 20 cm. column of the sand into the



Graphs I-IV.

beaker. It may thus be seen that the smallest algal cells are more readily distributed into the deeper layers of the soil by the downward movement of water. This observation could account for the presence of algae at depths of 1·5 cm. below the main zone of distribution of algae at the surface of the soil.

Penetration of Light into the Soil.

Photographic plates (extra-rapid panchromatic) were buried into a large square container of dry sand at an angle of about 30°, and the soil left exposed in the open for 24 hours. The plates were subsequently developed and the penetration of light into the soil was estimated by measuring the intensity of light transmitted through the plate by means of a Weston-Master exposure meter. In a similar experiment using wet sand, the results were not significant owing to the injurious effect on the photographic

plate of a 24-hour subjection to water-saturated soil. However, in order to obtain some kind of comparison, shorter term experiments were set up and the readings obtained were then extrapolated to obtain comparable results. In the dried sand it was found that the light could penetrate down to 1·5 cm. This is in agreement with the results obtained by directly counting the algae in the different layers of the soil. However, it is known that with very little light a plate becomes fully exposed within a day, and the light intensity measured at a depth of 1·5 cm. may be inadequate for the growth of algae. At 2·9 cm. it was found that there was no penetration of light at all. It can be seen by extrapolation from the short exposure of plates in wet and dried sand that the light penetration does not vary to any significant amount in the two conditions (see Graph IV). Thus it may be safely assumed that the penetration of light into the sandy soil in the water-saturated condition as used in the first experiment was limited to the top centimetre.

Discussion.

To the best of our knowledge the daily variation of the algal population of the soil has not been recorded in detail before. The cause of this variation is not completely understood, but it seems that the presence of nematodes and protozoa, and the changes in the water content of the soil may contribute. In the work presented here, nematodes and protozoa did not seem to play any significant role, since they were present in such low numbers. The important factor seemed to be the water content of the soil—an aspect which has been studied previously in some detail.

The remarkable resistance of algae to desiccation was demonstrated early in this century by Bristol Roach (1919). Further experiments by Petersen (1935) confirmed this observation. Petersen has shown that periods of very slow desiccation (of about one month's duration) of a soil may kill quite a considerable number of vegetative algal cells. However, this slow drying process is not of very common occurrence in sandy soils, and it is possible that any such slow-drying soils may induce the algae to produce resistant forms which would not be found in conditions where quick drying is possible. Bristol Roach (1919, 1920), using an intensive desiccation method, has shown that algae survived desiccation. The variation in the algal population in the present work occurred within a matter of hours, and the number of algae appeared to remain at a constant level of about 65% of the total algal population once the soil had reached the air-dried state.

Bristol Roach's results did show the presence of resistant forms of algal cells. However, such severe desiccation is not of very common occurrence in nature. Therefore the present results approximate more closely to the normal state of a soil system. This resistance to drought by algae is still far from being completely understood.

The minimum and maximum water levels needed for the growth of the algal flora in a sandy soil were examined and about 12% of the water-holding capacity (or 3% by weight) was required as the minimum amount needed for active growth. It may be possible that such a small amount of moisture, while inadequate for the growth of algae, could activate them into a state in which they could immediately start to grow and divide on the addition of extra water. This suggestion of activation is only hypothetical, since it is practically impossible during the experiment to keep the soil at a constant moisture level when such small amounts of water are involved. It may be presumed that under the experimental conditions the air immediately above the soil was 100% humid. Sometimes it was noted that a drop of water had condensed against the wall of the Petri dish, and if a soil particle had been in contact with it, the water content of the soil at this point would be much higher than the theoretical 3% of the experiment. It was observed by Schröder (1886) that diatoms died in soil containing 9·05% of water, but Petersen (1935) pointed out that the diatoms used by Schröder were hydrophilous species, and by using *Hantzschia amphioxys* and *Navicula mutica* he (1935) was able to show that full activity in the soil of these two species was

possible at a moisture level of 5·2%. This is comparable with the results obtained above.

Thus the variation in the water content of the soil is an important factor in connection with the algal population of the soil. It was only when near the air-dried state that the algal population decreased remarkably, whilst above this point it increased quickly to a constant steady level, which was finally independent to a certain extent of the excess water added. Between these two limits the water content of the soil plays a part in controlling the rate of the algal growth.

Distribution of Algae in the Soil.

Direct observation showed that in water-saturated soil the algal population was confined to the top few millimetres of the soil. When in an unsaturated state more algae could be found in the few centimetres immediately below the surface. Our experiments have shown that when the sand was saturated with water an anaerobic condition was established just below the surface (as indicated by the reduction of the rH_2 indicators). The influence of mineral salts on the speed of reduction of the dyes will be published in a separate paper, for which work is in progress. Direct counting of the algae confirmed the accumulation of the algal population to the top few millimetres under natural conditions. It would be expected that the anaerobic conditions present just below the surface would prevent the growth of algae, but it was found that if a small air bubble had been originally included in the soil, it provided enough oxygen for algae to grow in the anaerobic zone below the top few millimetres, and since there was photosynthetic regeneration of oxygen by the algae, it became a centre of re-oxidation and provided a suitable condition for other aerobic organisms to grow. This micro-ecological condition could only be produced with the presence of light. (In the dark the presence of air bubbles was not sufficient to re-oxidize any of the dyes which had become reduced during the early part of the experiment.) Experiments with photographic plates showed that light only penetrated the top centimetre of the soil. The penetration of light of different wave lengths in sand as recorded by Hoffmann (1949) with a photoelectric cell is very suggestive, and results were similar to ours. Since photographic plates require very little light to be fully exposed with long exposure time (a complete sunny day), it is doubtful whether this light intensity would be sufficient to ensure the growth of algae at depths greater than 1 cm. from the surface. Since coarse sandy soil is the most transparent to light and permeable to air, the present observation may be extended to other types of soil without involving any significant errors. Nevertheless, it must be remembered that in certain conditions where the soil is covered with water, e.g. rice fields, the presence of air bubbles below the water would provide a suitable starting point for algae to regenerate the oxygen needed by the root system.

One of us has shown (Pochon and Tchan, 1947) that in an unsaturated soil the top few centimetres were not under anaerobic conditions. If light cannot penetrate to this depth it may be possible that algae can grow heterotrophically, using the available air and an external organic carbon supply. Bristol Roach (1927, 1928) used sugars, and Treboux (1905) used organic salts to grow pure cultures of algae in the dark. The natural occurrence of sugar in the soil has always been doubted, and the use of organic salts by algae in the dark and in the soil has not been confirmed by direct experiments under natural conditions (Moore and Karrer, 1919, and Pugmaly, 1924). Petersen (1935) has shown that in the dark the presence of 0·5% of glucose did not increase the algal population. His work was done with a pure culture and sterile soil. With fresh unsterilized soil Petersen showed that algae did not multiply in the dark. Generally speaking, algae in pure culture are able to grow in the dark when suitable organic matter is provided. As Winogradsky (1932) has pointed out, the pure culture experiments have no absolute value in soil studies if the results are not confirmed by direct observation in the soil. Work with the total flora of the soil in natural conditions and with pure cultures has not at all times produced similar results, and modifications of one or the other have been evident. One of us has shown (Pochon,

Tchan, Wang, Augier, 1950) that the addition of fibrous cellulose into the soil induced the growth of the cellulose-decomposing bacterium, e.g. *Cytophaga*, but that with precipitated cellulose no growth occurred. Both forms of cellulose, however, were attacked by *Cytophaga* in pure culture. Therefore, if such a specific substance with only a slight modification of structure can induce two different microbiological reactions, then this conception may also be valid in the case of algae, as shown by results in both pure culture and our results in the natural conditions, when glucose was the added factor in both cases. Our experiments showed that in seminatural conditions the addition of glucose was not only unable to increase the algal population in the dark, but that even in the light the algae could not grow to any significant degree. In the deeper parts of the soil, where the anaerobic conditions were present, it was expected that no algal growth would occur, but even on the surface where the soil was in permanent contact with the air, the growth of algae was not noticeable. The microbial fermentation of glucose in these cases was indicated by a quick reduction of the rH_2 indicators and a characteristic smell. This fermentation seemed to be responsible for the inhibition of any algal growth, since once the fermentation had ceased (indicated by the absence of any smell and a negative test with Fehling's reagent for sugar) the growth of algae became noticeable in the soil kept in the light and formed a green cover on the surface within a few days. In the soil kept in the dark the growth was insignificant, which indicated that in the natural conditions, in the presence of the total flora of the soil, not only were the algae unable to compete with other micro-organisms for the sugar but there was an antagonistic effect produced by these organisms which seemed to prevent the algal growth. It may be that under special circumstances when available nitrogen is absent, only nitrogen-fixing organisms (bacteria or blue-green algae) would be able to grow, in which case the competition would be limited. After the fermentation of sugar had ceased and only organic salts remained, no evidence was produced to support the theory that growth of algae in the dark can proceed by utilizing organic salts, as was suggested by Treboux.

Thus all experiments have suggested that there was no growth of algae in the dark under natural conditions and that the subterranean algae are washed down from the surface. By filtering algae through sand it was obvious that the smaller sized algae can pass through 10 cm. of sand in a single filtration. Under natural conditions a heavy shower of rain could easily bring about such a condition. These results agree well with those of Petersen (1935) working with algae, and Burges (1950) with fungi.

Conclusion.

Using a method of fluorescent microscopy, the daily variation of the algal population in sandy soils was recorded. Hypotheses proposed to account for this variation were tested experimentally.

The quick growth and the physiological behaviour of the algae in a soil should benefit the soil in a number of ways: namely, by providing organic matter from photosynthetic activity; by a fast formation of a surface covering over the soil, thus diminishing erosion effects due to water and wind; and by the fixation by algae of soluble mineral nutrients which would otherwise be lost to the soil by drainage. This latter point has a bearing on the work done by Fuller and Rogers (1952), who found that algae in certain cases proved a favourable source of phosphate.

Experiments dealing with the vertical distribution of algae under natural conditions in the soil and their presence in the subterranean layers did not support the theory that the growth of algae in the dark is possible, even with the addition of an organic matter supply. Furthermore, it seems evident from the experimental data that the presence of glucose could create an antagonistic action which would inhibit the growth of algae in the soil. This hypothesis is a likely one, but is not yet fully understood.

The studies of algal physiological behaviour in the soil, using pure cultures, do not necessarily provide the complete solution to this problem. Algae must be studied, like other organisms, in the presence of the total flora of the soil to understand their role and behaviour in such a situation.

Acknowledgements.

The authors wish to thank Dr. J. McLuckie, Dr. N. C. W. Beadle, and Dr. and Mrs. F. Moewus, of the University of Sydney, and Dr. H. S. McKee, of the C.S.I.R.O., for their valuable criticism and help.

References.

Bristol, B. M., 1919.—*New Phytol.*, 18 : 92.
———, 1920.—*Ann. Bot.*, 34 : 35.
Bristol Roach, B. M., 1927.—*Ann. Bot.*, 41 : 509.
———, 1928.—*Ann. Bot.*, 42 : 317.
Burges, A., 1950.—*Trans. Brit. Mycol. Soc.*, 33 : 142.
Calmette, A., Boguet, A., Negre, L., Bretey, J., 1948.—Manuel technique de Microbiologie et Serologie, pp. 249-252. Masson et Cie, Paris.
Derx, H. G., 1950.—*Ann. Bogoriense*, 1 : 1-11.
Fuller, W. H., and Rogers, R. N., 1952.—*Soil Sc.*, 74, 6 : 417.
Hoffmann, C., 1949.—*Planta Bot.*, 36, 5 : 48-56.
Moore and Karrer, 1919.—*Ann. Miss. Bot. Gard.*, 6 : 281.
Petersen, J. B., 1935.—*Dansk. Bot. Ark.*, 8.
Pochon, J., and Tchan, Y. T., 1947.—*Ann. Inst. Past.*, 73 : 29.
Pochon,, J., Tchan, Y. T., Wang, S. L., Augier, J., 1950.—*Ann. Inst. Past.*, 79 : 376.
Pringsheim, E. G., 1950.—The culturing of Algae. The Charles F. Kettering Foundation.
Pugmaly, A. de, 1924.—Diss. Bordeaux.
Schröder, G., 1886.—*Untersuch. Bot. Inst. Tübingen*, 2 : 1.
Tchan, Y. T., 1945.—*C. R. Soc. Biol.*, November.
———, 1952.—Proc. Linn. Soc. N.S.W., 77 : 265.
Treboux, O, 1905.—*Ber. d.d. bot. Ges.*, 23 : 432.
Winogradsky, S., 1932.—*Ann. Inst. Past.*, 48 : 89.

EXPLANATION OF PLATE X, FIGS. 1, 2.

1. *Filter paper technique.*—The dyes from left to right are: neutral red, pheno-safranin, Nile blue, methylene blue.

Left beaker: When tap-water alone was added to the soil the reduction of the dyes was continuous within the anaerobic zone, and both methylene blue and Nile blue strips were reduced from within the top few centimetres to the bottom.

Centre beaker: When Derx's solution was added to the soil, the growth of algae took place more readily and was initiated by air bubbles in the soil. The products of algal growth in these areas oxygenated the soil to such an extent that re-oxidation of the dyes occurred in small areas which coincided exactly with these zones of growth. Such areas are visible in the Nile blue and methylene blue strips on the filter paper.

Right beaker: When a 1% glucose solution was added to the soil the reduction of the dyes was pronounced, due to the increase in anaerobic fermentation. Algal growth was inhibited and no re-oxidation areas were evident.

2. *Centre beaker, one week later.*

The re-oxidation of the dyes by algal growth was very pronounced in the methylene blue strip and was just evident in the Nile blue strip. The zone of algal growth exceeded the space occupied by the original air bubble, which initiated its growth, due to the production of oxygen from photosynthesis.

STUDIES OF N–FIXING BACTERIA. V.

Presence of Beijerinckia in Northern Australia and Geographic Distribution of Non-symbiotic N–Fixing Micro-organisms.

By Y. T. Tchan, Macleay Bacteriologist to the Society.

(Plate x, figs. 3, 4; one Text-figure.)

[Read 26th August, 1953.]

The distribution of aerobic N-fixing bacteria has been very intensively investigated in Australia except the northern part of this continent (Collins, 1952; Jensen, 1940; Jensen and Swaby, 1940; McKnight, 1949; Swaby, 1939). The species present are mostly *Azot. chroococcum*, occasionally *Azot. beijerinckii* and *Azot. vinelandii*. *Azot. beijerinckii* var. *acido-tolerans* has been isolated in the Sydney district (Tchan, 1953).

No *Beijerinckia* species have been reported. On the other hand, countries and islands near Northern Australia are inhabited by species of *Beijerinckia*. They have been isolated by Derx (1950) in recent years. The intensive movements of animals and human populations, and transport of dirt by wind could be a constant contaminating source of Australian soil by micro-organisms of the islands surrounding the country. The present paper is aimed to answer the following two questions:

(1) Are there any species of *Beijerinckia* in Northern Australia?

(2) What is their geographic distribution and their ecology?

Materials and Technique.

Soil samples: Samples were collected in a small sterile container at their natural moisture content. They were not a random sample. Most of them were collected along the roadside. Samples took two months to reach the laboratory. These consisted of 48 samples collected by the 1952 Australian Museum expedition; 15 samples around 19·5° latitude (Ayr, Queensland) collected by the Division of Plant Industry of C.S.I.R.O. were sent to me by air mail and immediately examined.

0·1 g. of each sample was inoculated into Derx's medium and Winogradsky's medium with sucrose as organic matter. After two months of incubation at 30°C., samples were considered as negative when no aerobic N-fixing bacterial colonies appeared. Positive samples were then analysed quantitatively by the liquid solid media technique described in an earlier paper (Tchan, 1952).

Chemical analyses were made for the C content by Walkley and Black's method. pH was determined by a glass electrode potentiometer with 1:10 soil water ratio. The P was estimated colorimetrically. Two extractions were used: (1) Burd's (Burd, 1948) contact equilibrium technique with water as solvent: (2) 3% citric acid at pH 3·5. As the *Beijerinckia* gave a final pH of 3·5 in their culture, this pH value was chosen for extraction.

Since samples were of small quantities (10–50 g.) it was impossible to make an extensive chemical analysis.

Discussion.

The results from this investigation showed for the first time that the soils of Northern Australia are inhabited by *Beijerinckia*. The number of positive samples is 17 over a total of 48 collected by the Australian Museum Expedition. It is very similar to the percentage of soils containing *Azotobacter* in the other parts of Australia.

The importance of these organisms in the N-economy of the soil cannot be discussed, since the 1952 drought and the long period between the time of collecting and analysis made the discussion very difficult. However, one sample gave 4,000 cells p.g. of soil.

TABLE 1.

Date, Localities, Soil.	Geological Formation of Soil.	*Azotobacter* p.g. of Soil.	*Beijerinckia* p.g. of Soil.	pH.	P. (1) Mg./kg.	P. (2) Mg./kg.	C. G./kg. of Soil.
Western Australia.							
(1) 20.5.52. 42 miles north of Hall's Creek on Wyndham Road, eastern Kimberleys. Residual red-brown soil. Flat savannah.	—	—	—	6·5	—	—	0·70
(2) 20.5.52. 18 miles south of Mabel Creek, eastern Kimberleys. Red-brown residual. Taken from about roots of Mitchell grass in open eucalypt country.	—	Sporadic	—	6·65	—	—	2·70
(3) 22.5.52. 20 miles south of Wyndham. Black sandy soil. From grass roots beneath eucalypt in open savannah.	—	—	—	6·5	—	—	2·0
(4) 26.5.52. Forrest River Mission, 15 miles south-east of Wyndham. Muddy soil from dry waterhole.	—	—	—	5·2	—	—	1·00
(5) 26.5.52. Forrest River Mission. Sandy loam. Collected from plain at base of quartzite hill.	—	—	—	6·25	—	—	0·90
(6) 12.6.52. Ivanhoe Station, northern Kimberleys. Black alluvium. Lightly timbered plain. Specimen from base of tree.	—	—	—	6·3	—	—	1·20
(7) 12.6.52. Ivanhoe Station. Black alluvium. Lightly timbered black soil plain. Specimen from base of grass clump.	Basalt	100	800	7·5	5	25	0·7
(8) 13.6.52. Newry Station between Ivanhoe and Auvergne. Brown soil from weathered quartzites and slates (Pre-Cambrian). Lightly timbered country. From amongst grass and tree roots.	—	—	—	8·1	—	—	0·40
(9) 13.6.52. Auvergne Station. Black residual. Sparsely timbered open country.	—	—	—	7·42	—	—	2·10
Northern Territory.							
(10) 13.6.52. Timber Creek near Victoria River Depot, Victoria River. Limy brown alluvium. Amongst grass roots ¼–1″ below surface.	Basalt	500	Sporadic	6·08	—	—	0·40
(11) 14.6.52. 72 miles north of Victoria River Downs Station. Basaltic soil. Lightly timbered plain with moderate grass development. Sample from bank of small water-course.	—	—	Sporadic	5·58	2·5	26	1·15
(12) 28.6.52. Port Keats Mission. Fine clay from bank of spring. Bank overhung by grass but clay collected did not appear to have been invaded by roots.	—	—	—	5·3	—	—	0·25
(13) 28.6.52. Port Keats Mission. Mangrove mud. Specimen from amongst mangrove roots exposed at low tide.	—	—	—	5·3	—	—	1·3
(14) 28.6.52. Port Keats Mission. Weathered ferruginous Permian sandstone soil. From amongst *Pandanus* roots near surface, in *Pandanus*-grassy hillside.	Sandstone	—	Sporadic	5·88	0·5	28	1·90

TABLE 1.—*Continued.*

Date, Localities, Soil.	Geological Formation of Soil.	*Azotobacter* p.g. of Soil.	*Beijerinckia* p.g. of Soil.	pH.	P. (1) Mg./kg.	P. (2) Mg./kg.	C. G./kg. of Soil.
(15) 28.6.52. Port Keats Mission. Black silt from marsh. Tea-tree marsh adjoining mangroves.	—	—	—	5·3	—	—	2·25
(16) 28.6.52. Port Keats Mission garden. Black silt. From base of banana tree.	—	—	—	5·5	—	—	2·30
(17) 28.6.52. Port Keats Mission area. Black soil and mould of fallen leaves. Light rain forest adjoining mangrove-fringed stream. 2″ below surface.	Clay	—	4000	5·7	0·8	12·5	2·0
(18) 28.6.52. Port Keats Mission. Black soil and leaf mould. Light rain forest adjoining mangrove-fringed stream. Depth : 6″.	Clay	—	Sporadic	5·6	0·6	12·0	3·0
(19) 30.6.52. 60 miles south of Darwin on Rum Jungle road. Sandy ferruginous soil. Open forest with undercover of sorghum. Specimen from roots of gum sapling.	Granite	—	Sporadic	5·55	0·6	20·0	2·0
(20) 30.6.52. 60 miles south of Darwin on Rum Jungle road. Sandy ferruginous. Open forest with sorghum. From amongst roots of sorghum.	—	—	—	5·5	—	—	0·35
(21) 30.6.52. Stapleton Creek, 65 miles south of Darwin. Soil weathered from Pre-Cambrian metamorphosed sediments. Savannah. From foot of grass clump.	Schist	—	Sporadic	5·3	1·0	12·5	2·9
(22) 30.6.52. Stapleton Creek. As above. From roots of scrub (light rain forest) along creek. Depth : 2″.	—	—	—	5·5	—	—	1·9
(23) 30.6.52. 105 miles south of Darwin. Sandy soil. Dry sclerophyll. Amongst eucalypts of adjoining small creek.	Granite	Sporadic	500	7·62	—	—	1·65
(24) 30.6.52. Katherine. Limy soil. Open forest with drying grass. Sample from grass and tree roots.	—	—	—	5·1	—	—	2·25
(25) 30.6.52. Katherine. Limy sand. Dry sclerophyll (gum). Taken from soil amongst fallen leaves.	Limestone	Sporadic	Sporadic	6·2	—	—	2·25
(26) 30.6.52. 19 miles south of Katherine. Depth : 2″. Ferruginous soil. Gum saplings with thick grass. Taken at sapling base amongst eucalypt and grass roots.	—	—	—	5·42	—	—	0·90
(27) 30.6.52. Maranboy tinfield, 30 miles south-east of Katherine. Sandy soil (weathered porphyry). Lightly timbered eucalypt forest with grass.	—	—	—	5·4	—	—	1·4
(28) 30.6.52. Mataranka. Ferruginous sandy soil. Lightly timbered gum forest with grass.	—	—	—	4·65	—	—	2·1
(29) 30.6.52. 30 miles north of Daly Waters. Black sandy soil. Lightly timbered forest.	Sandstone	—	Sporadic	5·5	0·6	75	3·0
(30) 30.6.52. 30 miles north of Daly Waters. Dried mud from depression. Collected from amongst roots of dead grass.	—	—	—	5·15	—	—	0·45

TABLE 1.—*Continued.*

Date, Localities, Soil.	Geological Formation of Soil.	*Azotobacter* p.g. of Soil.	*Beijerinckia* p.g. of Soil.	pH.	P. (1) Mg./kg.	P. (2) Mg./kg.	C. G./kg. of Soil.
(31) 1.7.52. Dunmara. Ferruginous sandy soil. Mallee thicket. Taken at tree base.	—	—	—	5·42	—	—	0·14
(32) 1.7.52. 110 miles south of Daly Waters. Red sandy soil. Semi-desert scrub. Taken amongst roots.	Sandstone	—	Sporadic	5·55	0·7	25	0·10
(33) 3.7.52. 50 miles east of Frewena on Barkley Highway. Ferruginous sandy soil (Cambrian). Semi-desert plain with moderate degree of shrubbery. Taken from grass roots.	—	—	—	6·65	—	—	0·5
(34) 3.7.52. 25 miles west of Soudan Station on Barkley Highway. Ferruginous sandy soil (weathered Cambrian). Semi-desert plain with rank grass and scattered shrubs. Taken from amongst roots.	—	—	—	6·25	—	—	0·4
Queensland.							
(35) 12.7.52. 25 miles south-east of Normanton. Red sandy soil. Lightly timbered open country.	—	—	—	6·28	—	—	1·0
(36) 12.7.52. Norman River, 16 miles west of Normanton. Damp river alluvium (water's edge). Riverside scrub.	—	—	—	5·0	—	—	—
(37) 12.7.52. Norman River, 16 miles west of Normanton. Dry river alluvium. Amongst riverside scrub 30 feet from water's edge.	—	—	—	5·4	—	—	0·25
(38) 13.7.52. 5 miles east of Gilbert River crossing, bank of tributary. River alluvium. River bank amongst light timber.	Alluvium	—	500	5·82	0·5	37·5	25·0
(39) 13.7.52. 20 miles west of Georgetown, Queensland, Granitic soil. Dry open forest.	Granite	150	500	7·25	2·0	76·0	26·0
(40) 14.7.52. Einasleigh River (near Einasleigh, Queensland). River alluvium. Amongst tea-tree roots on bank.	Granite ? Basalt ?	Sporadic	Sporadic	5·9	—	—	13·0
(41) 18.7.52. 35 miles W.N.W. of Innisfail, Atherton Tableland (2,500 feet). Basaltic soil. Rain-forest floor litter.	Basalt	Sporadic	Sporadic	5·1	2·5	37·5	28·0
(42) 19.7.52. 15 miles north of Cardwell. Litter of decaying leaves. Rain forest. Height probably about 500 feet.	—	—	—	5·7	—	—	21·0
(43) 19.7.52. 15 miles north of Cardwell. Grassy mud at streamside adjacent to rain forest. Alluvial soil.	—	—	—	5·0	—	—	6·5
(44) 21.7.52. 10 miles south of Ingham. Black alluvium. Grasslands adjoining canefields.	Granite	—	150	5·8	1·0	76·0	20·0
(45) 24.7.52. 50 miles south of Charters Towers. Brown sandy soil. Dry lightly-timbered open forest with grass (from base of grass clump).	—	—	—	5·8	—	—	2·0